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17. ABSTRACT (MAX. 250 WORDS) A study of the development of an autoinstructional program in physical science for first grade pupils was described. Objectives were to determine the extent to which first grade children could learn abstract concepts of molecular theory and use them to explain evaporation and condensation, and to discover the efficacy of an autoinstructional method using a teaching machine called the Videosonic Tutor.

In the first phase of the study, a 400-item program on molecular theory was administered to six pupils for 12 sessions each. Control groups were matched with the experimental groups. Results indicated that children mainly learned simple relationships. No differences in transfer ability were found between experimental and control groups. On the basis of the findings, program revisions were made in the second phase; this new program was presented under more highly standardized conditions. On a post-test, children showed better learning than in the first phase, but ability to generalize was still poor. In the third phase, items were revised again and, in addition, a special set of instructions for the physical operation of the Videosonic Tutor was programed. The experimental group scored much higher on a post-test than did the control group.

Tentative conclusions were that: first graders can learn abstract concepts of molecular theory and can use them to explain physical phenomena of evaporation and condensation; with one exception, the subjects' interests were held by the Videosonic Tutor for a three-week period; the use of still pictures in the Videosonic Tutor did not make it impossible to teach concepts involving motion; most of the subjects could use previously unfamiliar terms in addition to their own words in dealing with new situations, but some hesitated in verbalizing the terms; and the use of earphones eliminated distractions.

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VIDEOSONIC AUTO-INSTRUCTIONAL PROGRAM FOR TEACHING MOLECULAR THEORY IN THE LOWER ELEMENTARY GRADES--AN INTERIM REPORT OF PROGRESS AND PRELIMINARY FINDINGS

Purpose

This progress report summarizes the work of nine months of investigation in the development of an auto-instructional program for first grade pupils in physical science. The objectives of this program were two-fold:

1. To determine to what extent first grade pupils could learn certain abstract concepts of molecular theory and use them in explaining the physical phenomena of evaporation and condensation.
2. To discover the efficacy of an auto-instructional method involving the use of a teaching machine called the Videosonic Tutor.

The work so far has been carried out in three phases.

Phase 1 (October to January)

Seventy children in the first and third grades were given individual oral interviews to discover how children of this age talk about physical phenomena. These results were used as a starting point for the program.

Approximately 400 items were then constructed. These items dealt with the following topics as related to molecular theory: the three states of matter, evaporation, condensation, and air pressure. For each item in this series, a large picture card was shown to the pupil, an accompanying commentary was read, and the pupil was asked to answer a question by pointing to the correct one of several pictures on the card.

This program was tried out with 6 pupils, a total of twelve sessions each. At the conclusion of this instruction, the 6 pupils and their matched controls were given an individual oral interview in which the pupils were asked to give in their own words answers to questions on the topics covered.

Results for this first phase indicated that children learned mainly the simple relationships (e.g., molecules move faster in hot water than in cold). The experimental group did no better than the controls on questions which asked them to generalize to new situations.

Phase 2 (February to April)

On the basis of the preliminary findings, the following revisions were made in the program:

1. Items dealing with air pressure were eliminated in order to focus upon fewer critical concepts.
2. Review items were added giving a more extensive treatment of topics previously covered.
3. Items were added giving a greater variety of illustrations of physical phenomena, thus providing greater practice in transferring to "life-like" situations.
4. The sequence was made more logical.
5. Verbal commentary after each item was revised to include both a phrase of approval and an explanation of why the answer was correct.
6. Pictures were made much easier to "read". Important elements were enlarged and made more simple and distinctive.

As this program was being revised, it was tried out with three children in the first grade.

The program was then presented to children under more highly standardized conditions. The commentary was recorded on tape. Each child recorded his answer by pressing buttons on a mock-up of the keyboard of the Videosonic Tutor. Like the final device, white lights went on when the wrong button was pressed, and green lights went on when the correct button was pushed. Twelve children were given instruction in this way with 350 items.

On the post-test, another oral interview, the children demonstrated better learning than did the children in Phase 1. However, these children also showed inability to generalize to new questions. They did not demonstrate that they could use these concepts in offering explanations for physical phenomena similar to but not identical with those presented in the program.

Phase 3 -- Instruction with the Videosonic Tutor

(May through August)

Items were revised again along the directions taken in Phase 2 except that no topics were deleted. In addition, a special set of instructions for the physical operation of the Videosonic Tutor was programmed.

Subjects. A pre-test, which measured children's knowledge of vocabulary used in the program (e.g., "desert", "oil") was given as a basis for matching experimental children with their controls. Matching of pupils also considered the teacher's assessment of the pupils' attentiveness, maturity, and intellectual ability. Thirteen first grade pupils, who represented a range of ability, made up the experimental group and a like number, the control group. Children in the latter group received no special instruction.

Operation of the Videosonic Tutor. Instruction during Phase 3 was carried on exclusively by one Videosonic Tutor. At the beginning of each daily session, a research assistant seated the pupil in front of the device and started it. For each sitting approximately 36 slides were projected in sequence upon a viewing screen at the front of the Tutor. These slides usually consisted of a central picture with two or three sub-pictures constituting the alternatives to the question to be asked. While each slide was projected, the child heard through earphones a commentary from a tape recorder in the device.

This commentary supplied appropriate information about the picture and asked a question. After each question, the tape recorder automatically turned off, at which time the pupil pressed a button corresponding to the sub-picture he chose as his answer to the question. If he was correct, a green light was lighted near the button pressed, the tape recorder started to play again, and the child heard words of approval along with a brief explanation as to why this answer was correct. A new slide was then automatically presented, and the process was repeated.

When an answer was in error, the green light did not go on, and the child had to clear the keyboard by pushing a yellow button before he could try again. The program would not advance until the pupil pressed the correct button.

General Procedure. Children appeared individually at a room made available for the auto-instructional program. A research assistant was always present for the purpose of loading the device and maintaining a record of each child's performance, but this assistant gave no instruction of any kind.

Each child spent approximately 15 to 20 minutes with the device each day for a period of twelve or thirteen days. On a few occasions children completed two lessons in one day. The machine was in operation, therefore, four to five hours daily.

Upon completing the lesson, each child returned to the classroom and informed the next pupil that it was his turn, without interrupting the ongoing classroom activity.

The Videosonic Instructional Program. Content of the instructional unit consisted of 432 items organized into thirteen lessons which were related to (1) the operation of the Videosonic Tutor, (2) the three states of matter and (3) evaporation and condensation. A distribution of the items by topics is to be found in Table I.

TABLE I

Distribution of Items by Topics

Topic		Number of Item
a.	operation of Videosonic Tutor	26
b.	code for interpreting molecular motion and direction	56
c.	composition of molecules as elementary particle	42
d.	movement of molecules as related to states of matter	86
e.	the concept of molecular attraction	21
f.	evaporation (vaporization)	80
g.	temperature as related to molecular motion	44
h.	condensation	66
i.	the distinction between gas and gasoline	8

These items were arranged in sequence by which the child gradually expanded his knowledge to a point where he marked complex responses with ease and accuracy.

The entire program was built around a logically organized series of generalizations (definitions, principles, etc.). For each generalization a sequence of items was developed beginning with a review of those ideas important for this generalization. Other preparatory material was presented, and then the child was introduced directly to the generalization. In this process the child was usually given a wide variety of illustrations and analogies. A number of items to "clinch" the learning followed. Throughout the remainder of the program, however, each generalization was reviewed and extended periodically by new items.

The way in which students learn from auto-instructional materials can be seen from the illustrated sequence of items shown in Appendix A. These samples may give some idea of the manner in which specific knowledge and generalized concepts were developed and gradually extended.

Post-Test. Within a day following the completion of the Videosonic instructional program, children in the experimental and in the control group were given a post-test of approximately ten minutes' duration. This consisted of a standardized interview (see Appendix B) in which the child was presented with actual physical phenomena and asked, with reference to these phenomena, to (1) explain what had happened, (2) predict what would happen subsequently, and (3) show how he would make certain things happen. For example, the child was shown a plastic box in which

there was mercury, a substance that had never been referred to in the program. He was asked whether "this thing in the box" was a solid, liquid, or gas. The child was also requested to give reasons for his answer. In another problem, the pupil was shown an actual glass of ice water with these remarks: "A little while ago I dried the glass off with a cloth. But look at the water on the outside of the glass. See, the cold glass is wet. Feel it with your fingers.....How did the glass get wet on the outside?"

An interviewer and a recorder, both of whom were strangers to the experimental and the control children, conducted the post-test. These two assistants were not told which children had received the auto-instruction. Each child's oral response to each question was recorded, and the records were subsequently read and scored by these same assistants.

Preliminary Results. All except one of the experimental children showed higher post-test scores than did their controls, a difference which is significant at the .01 level. The one exception was a girl who had shown successful performance throughout the program but during the interview appeared to be quite withdrawn and answered only five questions, all of them correctly.

The mean score of the experimental group on the post-test was 66% of the total possible, while the control group mean was 22%. Three of the experimental group made scores higher than 90% correct, demonstrating an unusual mastery of the concepts taught in the program. The contrast in quality of solutions given to problems by pupils in the control and experimental group

is illustrated by two answers to the question how the outside of a glass of ice water became wet. A typical child in the control group said, "The water in the inside soaked through." But one of the experimental youngsters said, "Molecules come and hit the cold glass and slowed up---.makes drops."

The daily lessons varied in difficulty. The average error for each day ranged from 7.1% to 19.4%. The average child missed 14.1% of all items in the entire program.

Individual children differed in the number of errors they made. One pupil made as few as 7.1%, while another, with the lowest reading readiness score, made as many as 29.3%. However, on the post-test this pupil with the large error rate showed greater achievement than any individual in the control group.

Success on the post-test was significantly related to the number of errors made during the auto-instructional program (rho equals .60). There was some evidence that the program was more appropriate for children with particular characteristics such as a high reading readiness and strong study habits as rated by teachers.

The final question in the videosonic instructional program asked the pupils if they would like to continue learning new things in this fashion. All children except one responded by pushing a button indicating "yes". The one exception shortly thereafter said to the assistant, "I answered 'no' just for a joke." The classroom teacher from whose class the children were drawn reported that children looked forward to the program each day. Many of the children spontaneously took ideas from the auto-instructional materials, using them in the creation of their

stories for classroom purposes.

The questions asked in the post-test oral interview along with the percent of the experimental group who satisfactorily answered each particular question may be found in Appendix B.

Tentative Conclusions.

1. While there are great individual differences, first grade pupils can learn certain abstract concepts of molecular theory and use them for the explanation of physical phenomena of evaporation and condensation. It appears that further improvements in the program will result in a greater proportion of children showing almost perfect achievement.
2. The Videosonic Tutor held the interest and attention (with one possible exception) of all of these six year old children over a period of almost three weeks. While it is impossible to guarantee that this interest will continue on the part of young children for a full school year, it seems highly probable that with appropriate programming this indeed would be true.
3. Even though no motion pictures were used in this program, the correct concept of molecular movement was acquired by approximately three quarters of the children. This suggests that the use of still pictures in the Videosonic Tutor does not necessarily make it impossible to teach concepts involving motion.
4. Even though the multiple-choice method was used throughout as the sole means for responding, most of these children demonstrated in the interview that they were able to use

previously unfamiliar terms as well as their own words in dealing with the new situations.

5. However, some of the children showed some hesitation in verbalizing these previously unfamiliar terms. This was probably because they had never before been called upon to vocalize them overtly. It seems quite probable that if the Videosonic Tutor had been equipped to permit the recording of the child's voice and considerable practice in speaking these terms had been called for, the pupils would have shown (a) more facile expression of the terms and (b) more frequent use of such language in the solution of new problems.
6. The use of earphones by the pupils eliminated what otherwise would have been a distraction. For example, occasional visitors went unnoticed by the child even though these persons carried on a normal conversation in the room.

Further Work. During the remainder of Phase 3, additional cases from the first grade will be collected. Arrangements are now being made to do this study at least once and hopefully twice during the current summer session in local schools.

Prior to the fall semester, the items in the current program will be revised a final time on the basis of the try-outs in Phase 3. During the fall semester this revised program will be used in a number of experiments as outlined in the original proposal for this project.

APPENDIX A

Lesson Four

It is the purpose of this lesson to help children learn that molecules in a liquid move past each other and that molecules in a solid move back and forth in the same relative position. To this end the children will a) learn a motion code so that they can interpret and respond to pictures which depict molecular movement and b) relate these pictures to the characteristics of liquids and solids.

FRAME 1 This watch is a solid. Does it change its shape?*

REVIEW ITEM
You're right! You have learned that all solids keep their shape.*

FRAMES 2 - 8
ITEMS WHICH TEACH THE MOTION CODE
Which arrow shows us the direction this man is walking?*

Good for you! The man is walking forward.*

This airplane is moving. If you look closely you can see the lines behind it. Which arrow shows the way the airplane is flying?*

Right you are!*

This man has just rolled a ball. Which arrow shows the way this ball is rolling?*

Right! The lines behind the ball tell you the direction the ball is moving.*

Which picture below shows the way that these three balls are moving?*

You're right!*

Here is a picture of a ball rolling towards the wall. See the lines behind it. Which picture at the bottom shows a ball rolling away from the wall?*

Good for you. You know that the lines behind the ball tell the direction in which the ball is moving.*

Which picture shows a man who has just thrown a ball?*

Right you are!*

Are these balls moving in all directions?*

Good for you! The lines behind the balls show that they are moving in all directions.*

FRAMES 9 - 15

ITEMS WHICH RELATE THE MOTION CODE TO MOLECULAR MOVEMENT IN A SOLID AND LIQUID

Here are some molecules moving all around, sliding past each other. These are not the molecules of a solid. They are the molecules of a liquid which move all around rather than back and forth. Are these molecules moving back and forth?*

Of course not. You're right! These molecules are moving all around.*

Here is a picture of molecules. Look at the lines behind them carefully. You see that the molecules are not moving back and forth like in a solid. They are sliding all around. Are these molecules of a solid?*

Good for you! These are not molecules of a solid.*

You remember that molecules of a solid move back and forth, and you know that molecules of a liquid move all around, sliding past each other. Which picture shows the molecules of a liquid moving all around?*

Right you are! Molecules in a liquid move all around each other.*

Water is a liquid because its molecules move around and slide past each other. Is the water in the glass a liquid?*

Right! Water is a liquid.*

Here are two drops of water. Water is a liquid. Which picture shows the way the water molecules will move if we could see them moving all around?*

Very good!*

Remember that when molecules move around and slide past each other, we have a liquid. Here is a drop of orange juice. Orange juice is a liquid. Which picture shows how the molecules in this drop of orange juice will move?*

Right you are! The molecules in orange juice move around and slide past each other.*

Here is a drop of water. You can see the molecules in the circle over this drop of water. These molecules are moving. Are they moving around and past each other?*

Good for you! Molecules in water move around and past each other.*

FRAMES 16 - 22

ITEMS WHICH TEACH OTHER CHARACTERISTICS OF SOLIDS AND LIQUIDS

There is water in this glass. Water is a liquid. It is going to be poured into a flat pan. What will the water look like after it is poured?*

That's right! The water takes the shape of the pan.*

There is a liquid like water in this glass. Suppose we pour the liquid into a big round bottle like this. What will the liquid look like inside the bottle?*

Right you are! The shape of the liquid will be just like the inside of the bottle.*

Which picture shows a solid which keeps its shape in the glass?*

Good! A solid keeps its shape but a liquid does not.*

Ink is a liquid. What will happen if this bottle of ink tips over?*

That's right. A liquid will flow and spread out all over the desk.*

This service station man is pouring oil into the engine of the car. See how the oil pours out. It does not keep its shape. Is oil a liquid like water, or a solid like ice?*

Right! Oil changes its shape so it is a liquid like water.*

Two of these pictures show solids. One picture shows a liquid. Which one is a liquid.*

You're right! The dripping wax from the candle is a liquid. It runs and flows.*

FRAMES 23 - 35

ITEMS WHICH SUMMARIZE PREVIOUS LEARNINGS AND CALL FOR APPLICATION

Here are some molecules in a liquid. The lines behind them show that they are sliding around each other. Below are pictures of a piece of string, a drop of oil, and a rock. Which one of these has molecules which act like the ones at the top?*

Good for you! The oil is a liquid, so its molecules will move all around each other.*

To this glass of water we add a drop of colored water. See it land in the water. Which picture shows how the glass of water will look after a few minutes?*

Good, you knew that the water molecules will move all around and the colored water will start to mix.*

Look how the colored water is spreading out in the water. This is because the molecules are sliding past each other. What will this glass look like after while?*

Right you are! Because both the red water molecules and the water molecules move in all directions and slide past each other. They will mix all through the glass after a while.*

In this picture see the colored water spreading all through the glass. The reason it is spreading is that the molecules of the colored water are sliding all around past other molecules. Which picture shows why the colored water is spreading through the glass?*

Right you are! The molecules are sliding all around past each other.*

Look at the waterfall. How would its molecules move? Which picture below shows the kind of molecules in a waterfall?*

Right, the water is a liquid. Its molecules slide all around, not back and forth as in a solid.*

If you try to hold some water with your fingers, it slips right through. Remember that water molecules move in all directions. Which picture shows why this happens?

Good for you! The molecules move in all directions and do not keep their shape. That is what makes it hard to pick up water in your fingers.*

If we could see the molecules of a drop of oil they would look like this. Can oil change its shape?*

That's right! Oil is a liquid.

This glass has something in it. The molecules are moving back and forth. They are not sliding all around as in a liquid. If the glass is tipped over, will the green stuff change its shape and run all over or will it keep its shape like a solid? Which picture shows what will happen?*

You are right! The green stuff will keep its shape because its molecules are not sliding all around each other. It is a solid.*

In water, molecules do not move back and forth. They slip around each other. You can see the molecules slipping around each other inside this drop. Which picture shows the way molecules move in a lake of water?*

Good! You knew that the molecules in a drop of water move all around.*

This is a wooden board. It is a solid because it doesn't change its shape. Which picture shows the way molecules are moving inside the board?*

Good for you! Molecules in a solid move back and forth.*

The molecules in a solid move back and forth. The molecules in this brick move back and forth. Which picture shows the way molecules would look in a rock if you could see them?*

Right you are! Molecules in a solid move back and forth.*

This rock is made of molecules. Suppose we could see some of the molecules in this rock. How would they be moving? Which picture shows?*

Right, the molecules in a rock are moving back and forth. A rock is a solid.*

If you could see the molecules in this lake, how would they be moving? Which picture shows?*

Right, the water in the lake is a liquid. The molecules in a liquid slide around each other.*

APPENDIX B

POST TEST AND RESULTS FOR EXPERIMENTAL GROUP

RESULTS	
PERCENTAGE OF PUPIL CORRECT RESPONSES	RANK ORDER OF DIFFICULTY

Videosonic Project in Molecular Theory

Oral interview of Evaporation and Condensation

Child's Name: _____, Grade____, Teacher:_____

Date Tested: _____ Time Started:_____ Time finished:_____

Interviewer's name:_____ Recorder's name:_____

Instructions: Establish rapport with child first. Try hard to set him at ease; be sure child does his best on these items. Read questions as given below. If child does not seem to understand, repeat the question or part of it. Do not re-phrase the question or give the child any extra help. However, give the child plenty of approval for trying or for just coming to the interview. You may make other comments (not related to these topics) to keep him relaxed and interested.

I. (Hold up mercury in plastic box. Be sure mercury doesn't ever leak out.)

54	3	1. "Here is something in this box. Is this thing in the box a solid, liquid, or a gas?"
62	6	2. "How can you tell it is a _____" (whatever the child said)?
62	6	3. "How do you know that it isn't a gas?"

II. (Place a drop of water on the table in front of the child.)

77	14	4. "Here is a drop of water on the table. What is this water made of?"
		4A. (If child says "molecules," say "Very good. Water <u>is</u> made of molecules.")
		4B. (If child does not say "molecules," say "Well, I was thinking of molecules. Water is made of molecules.")
100	20	5. "If we heat this drop of water up and make it hot will the molecules go faster or more slowly?"
69	11	6. "If we leave the drop of water on the table, after a while it will dry up. What happens to the molecules of water as this drop dries up?"
62	6	7. "What does the water become after it dries up?"

**** "Do cats like to drink milk?"

	III. (Blow on your hand.)
92	18	8. "I'm blowing on my hand. You blow on yours. Do you feel the air on your hand? What is air made of?
		8A. (If he says "molecules," say "Fine. Air <u>is</u> made of molecules.")
		8B. (If he does not say "molecules," say "Well, I was thinking of molecules. Air is made of molecules.")
85	16	9. "Is air a solid, liquid, or a gas?" _____
31	1	10. If he says anything, "How can you tell that air is a _____"?
		IV. (Move glass of ice water in front of child.)
62	6	11. "There is water vapor in the air in this room. See this cold glass. What happens to the molecules of water vapor when they come near the glass?"
62	6	12. "A little while ago I dried this glass off with a cloth. But look at all the water on the outside of the glass. See, the cold glass is wet, Feel it with your fingers..... How did the glass get wet on the outside?"
46	2	13. What happens to the molecules of water vapor when water vapor condenses?

****** "What is it that lives in water all the time?"

V. (Allow child to smell perfume without seeing bottle or liquid. Use cloth.)

85	16	14. "Do you smell something? Is this <u>smell</u> a liquid, solid, or gas?"
54	3	15. "How can you tell that the smell is a _____?"

VI. (Show the child a drop of water on a rose and say:)

69	11	16. "Very often in the morning, you can see drops of water like this one on the grass and the flowers. You can see these drops of water even though there has been no rain and the flowers and grass have not been sprinkled. How did these drops of water get on the flowers and the grass?"

RESULTS				
		*****		"Show me with your hand how a fly moves in the air." (Do it with child.)
77	14	VII.	17.	"Show me with your hands how molecules move. First, show me how they move in a solid. Show me with your hands." (Describe motion of hands. Is child making hands move back and forth?)
69	11		18.	"Show me with your hands how molecules move in a liquid?" (Is child moving his hands around, over and under, each other?")
		*****		"What kind of animal barks?"
		VIII.	19.	"Do molecules of water attract each other?"
92	18		19A.	(If child says "yes," say "Yes they <u>do</u> attract each other.")
			19B.	(If child says "no" or "I don't know" say, "Well, yes, they <u>do</u> attract each other.")
54	3		20.	"What would you do to water to make the molecules overcome their attraction? To each other?"
100	20	IX.	21.	"Can you ever see molecules?"

**** (Ask any other easy question which child might like. Give child plenty of approval and appreciation. These questions are not to be scored.)